21. How was this proposal developed?

Staff began the development of the proposal with the creation of the Maritime Air Quality Technical Working Group (MWG) in late 2001. During MWG meetings, staff discussed different approaches to reduce marine vessel emissions at the conceptual stage. In late 2004, staff began a series of public workshops focused on the proposed regulation for auxiliary engines. Extensive efforts were made to ensure that the public and affected parties were aware of and had the opportunity to participate in the development of this proposal. For example, meetings to discuss the proposal were held at times and locations that encouraged public participation, including meetings at California ports and evening sessions. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers, the U.S. Coast Guard, local and federal air quality agencies, and other parties interested in marine emissions. These stakeholders participated both by providing data and reviewing draft regulations, and by participating in open forum workshops, in which staff directly addressed their concerns. During these meetings, ARB staff discussed a number of regulatory strategies at the concept stage, including the current proposal. Nearly 400 individuals and/or companies were notified for each workshop through a series of mailings. Notices were posted to ARB's marine and public workshops web sites and e-mailed to subscribers of the marine electronic list server.

As a way of inviting public participation and enhancing the information flow between ARB and interested parties, staff created a commercial marine Internet website (http://www.arb.ca.gov/msprog/offroad/marinevess/marinevess.htm) in 2001. Since that time, staff has consistently made available on the website all related documents, including meeting presentations and draft versions of the proposed regulatory language. The website has also provided workshop and meeting notices and materials, other marine related information, and has served as a portal to other websites with related information.

Recognizing that other states also have concerns about marine emissions, and that uniformity of requirements should be promoted, ARB set up a States Marine Emission Reduction Group. ARB staff schedules periodic meetings with this group, which includes regulatory agencies in other states and Canada.

22. How does the proposed regulation relate to the State Implementation Plan for Ozone and PM?

On October 23, 2003, ARB adopted the *Proposed 2003 State and Federal Strategy for the California State Implementation Plan* (State and Federal Strategy). The State and Federal Strategy identifies the Board's regulatory agenda to reduce ozone and PM by establishing targets to develop and adopt new measures for each year from 2003 to 2006. In addition to meeting federal requirements, the Statewide Strategy ensures continued progress towards California's own health-based standards. The State and

Federal Strategy includes a commitment to reduce emissions from the existing fleet of ocean-going vessels. The proposed regulation will help to fulfill this commitment.

23. How does the proposed regulation relate to ARB's goals for Environmental Justice?

Environmental Justice is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. ARB's Environmental Justice Policies are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB's activities.

The proposed regulation is consistent with the environmental justice policy to reduce health risks from toxic air contaminants in all communities, including those with low-income and minority populations, regardless of location. The proposal will reduce diesel PM, NOx and SOx emissions from ocean-going vessels for all communities near California ports and shipping lanes, particularly for communities near the ports of Los Angeles, Long Beach and Oakland.

24. What future activities are planned?

In addition to activities associated with monitoring and compliance with the proposed regulation, staff recognizes the need to conduct a number of other activities. These activities include:

- outreach to the vessel operators that only visit California ports occasionally to ensure that they are aware of the requirements of the proposal;
- develop procedures to implement the Noncompliance Fee Provision, and ensure funds are used effectively to reduce port and marine emissions; and
- continue to encourage the U.S. EPA and the IMO to take a more active role in reducing emissions from ocean-going vessels.

In addition, staff recognizes the need to achieve additional emission reductions from ocean-going vessels. Reducing emissions from the main propulsion engines on ocean-going vessels will be the next priority. While the emissions from these engines are mostly emitted outside the ports, they contribute far more emissions than those affected by the current proposal. Another area for investigation is the potential for emission reductions from vessels that make frequent calls at California ports. One such option for these vessels may be the use of shore-side power. ARB staff is developing a study of the feasibility of implementing shore-side power hookups that will investigate the technical and economic issues. These and other potential emission reduction strategies will be evaluated as part of an effort to develop a port and intermodal goods movement Comprehensive Emission Reduction Plan that will define the strategies needed to reduce public health impacts from ports and related activities. This effort, which is part of the Governor's Phase II Goods Movement Action Plan, is currently underway and it is expected to be completed by the end of 2005.

25. What is staff's recommendation?

We recommend that the Board approve the proposed regulation presented in this report (Appendix A). The proposal will reduce emissions of diesel PM, NOx, and SOx, resulting in significant health benefits to the public. In particular, communities near California's major ports and shipping lanes benefit from reduced exposure to the potential cancer risk from diesel PM. Staff believes that the proposal is technologically and economically feasible and necessary to carry out the Board's responsibilities under State law.

REFERENCES

(Directive 2005/33/EC) European Union Official Journal, Directive 2005/33/EC of the European Parliament and of the Council of 6 July 2005 amending Directive 1999/32/EC

I. INTRODUCTION

In this chapter, the Air Resources Board (ARB or Board) staff provides an overview of the Staff Report, discusses the purpose of the proposed regulation ("proposal"), and discusses the regulatory authority ARB has to adopt the proposed regulation. We also discuss the process used to include all interested stakeholders in the development of the proposal, including providing opportunities for meaningful public participation.

A. Overview

This report presents the proposed regulation to reduce emissions of diesel particulate matter (PM), nitrogen oxides (NOx), and sulfur oxides (SOx) from diesel auxiliary engines used on ocean-going vessels within 24 nautical miles of the California Coastline. A detailed summary of the requirements of the proposal are included in Chapter V. The report also shares the information that ARB staff used in developing the proposal. This information includes:

- the health effects associated with exposure to diesel PM, NOx, and SOx emissions (Chapter II);
- a description of the affected industry and the existing regulations designed to reduce emissions from auxiliary engines used on ocean-going vessels (Chapter III);
- the diesel PM, NOx, and SOx emission inventory and health risks posed by auxiliary engines used on ocean-going vessels (Chapter IV);
- a summary of the provisions in the proposal, and a discussion of the regulatory alternatives to the proposal that were considered (Chapter V);
- a discussion of the technical feasibility of using the fuels specified in the proposal, and other control technology options (Chapter VI);
- the environmental impacts of implementing the proposal (Chapter VII); and
- the estimated costs to industry and the fiscal impacts of these costs (Chapter VIII).

In developing the proposal, there were a number of technical and policy issues that had to be addressed. These included the impacts of the proposal on diesel-electric vessels, vessels requiring modifications to use distillate fuel, and the scope of the Alternative Compliance Plan provision. These and other key issues are discussed in Chapter IX, Additional Considerations.

The text of the proposal and other supporting information are found in the Appendices.

B. Purpose

The purpose of this proposal is to reduce emissions of diesel PM, NOx, SOx, and "secondarily" formed PM (PM formed in the atmosphere from NOx and SOx emissions). Diesel PM emission reductions are needed to reduce the potential cancer risk, premature mortality and other adverse impacts from PM exposures to people who live in the vicinity of California's major ports and shipping lanes. Reductions in diesel PM and SOx (which forms "secondary" sulfate PM in the atmosphere) will also contribute to regional PM reductions that will assist in California's progress toward achieving State and federal air quality standards. Reductions in NOx, an ingredient in the formation of ozone pollution, will help reduce regional ozone levels and secondary nitrate PM. The health impacts of these pollutants are described in Chapter II.

C. Regulatory Authority

Under State and federal law, ARB can regulate both criteria pollutant and toxic diesel PM emissions from marine vessels. Health and Safety Code (H&SC) sections 43013 and 43018 authorize ARB to regulate marine vessels to the extent such regulation is not preempted by federal law. Also, H&SC § 39666 requires ARB to regulate emissions of toxic air contaminants (TAC) from nonvehicular sources, which include ocean-going vessels. The proposed regulation reduces or limits diesel PM, which is both a TAC and criteria pollutant, and NOx and SOx, which are both criteria pollutants.

The proposed regulation is neither preempted under federal law, nor does it violate the Commerce Clause. Federal authorization under section 209(e) of the Clean Air Act (CAA) is required for regulating new nonroad engines and for requiring retrofits on existing engines. Ocean-going vessel engines, by definition, fall within the category of nonroad engines. However, no federal authorization is required for implementing in-use operational requirements on existing marine vessels and their engines.

Further, the proposed regulation does not conflict with the Ports and Waterways Safety Act (PWSA) and U.S. Coast Guard regulations. As a non-discriminatory regulation with substantial benefits, the proposed regulation does not violate the Commerce Clause. And federal and state cases support our authority to regulate both U.S. and foreign-flag vessels within California Coastal Waters. Therefore, federal law does not preempt the proposed regulation, nor does the regulation violate the requirements of the Commerce Clause.

The ARB's legal authority to promulgate the proposed regulation is discussed in more detail in Appendix B.

D. Public Outreach and Environmental Justice

Environmental Justice

ARB is committed to integrating environmental justice in all of its activities. On December 13, 2001, the Board approved "Policies and Actions for Environmental Justice," which formally established a framework for incorporating Environmental Justice into ARB's programs, consistent with the directive of California State law. Environmental Justice is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. These policies apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities.

The Environmental Justice Policies (Policies) are intended to promote the fair treatment of all Californians and cover the full spectrum of ARB's activities. Underlying these Policies is a recognition that the agency needs to engage community members in a meaningful way as it carries out its activities. People should have the best possible information about the air they breathe and what is being done to reduce unhealthful air pollution in their communities. The ARB recognizes its obligation to work closely with all communities, environmental and public health organizations, industry, business owners, other agencies, and all other interested parties to successfully implement these Policies.

During the development process, ARB staff searched for opportunities to present information about the proposed regulation at places and times convenient to stakeholders. For example, the meetings were held at times and locations that encouraged public participation, including meetings at California ports, and evening sessions. Attendees included representatives from environmental organizations, community groups, port administration, vessel operators, engine manufacturers, fuel producers, the U.S. Coast Guard, local and federal air quality agencies, and other parties interested in marine emissions. These individuals participated both by providing data and reviewing draft regulations, and by participating in open forum workshops, in which staff directly addressed their concerns. Table I-1 below provides meeting dates that were made to apprise the public about the development of the proposed regulation.

Table I-1: Workshop/Outreach Meeting Locations and Times

Date	Meeting	Location	Time
December 6, 2001	Maritime Working Group	Port of Long Beach	10:30 a.m.
April 9, 2002	Maritime Working Group	Port of Long Beach	9:30 a.m.
May 23, 2002	Maritime Working Group/Incentives Subgroup	Phillip Burton Federal Building, San Francisco	10:00 a.m.
July 26, 2002	Maritime Working Group	Port of Oakland	9:00 a.m.
December 3, 2003	Maritime Working Group	Port of Los Angeles	10:30 a.m.
April 8, 2004	Maritime Working Group	Cal/EPA Building, Sacramento	10:00 a.m.
Sept. 9-10, 2004	Conference on Air Quality, Int'l Trade and Transportation	Marina Hotel, San Pedro	10:00 a.m.
October 27, 2004	No Net Increase Air Quality Task Force	Sheraton LA Harbor Hotel, San Pedro	1:00 p.m.
November 10, 2004	Public Workshop	Cal/EPA Building, Sacramento	1:30 p.m.
January 19, 2005	Port Community Advisory Committee	Port of Los Angeles	4:30 p.m.
February 24, 2005	California Air Resources Board: Board Meeting	Cal/EPA Building, Sacramento	9:00 a.m.
April 7, 2005	Environmental Law Super Symposium	Omni Hotel, Los Angeles	1:00 p.m.
May 18, 2005	Public Workshop	Cal/EPA Building, Sacramento	1:00 p.m.
August 15, 2005	Workgroup Meeting	Teleconference	9:00 a.m.
August 24, 2005	Public Workshop	Port of Long Beach	1:00 p.m.
August 24, 2005	Community Workshop	Long Beach Senior Center	6:00 p.m.
October 4, 2005	Workgroup Meeting	Teleconference	1:30 p.m.
October 7, 2005	Bunkerworld Forum: Marine Fuel Sustainability	Hyatt Regency, San Francisco	11:00 a.m.

The proposal is consistent with the environmental justice policy to reduce health risks in all communities, including those with low-income and minority populations, regardless of location. The proposal will achieve the most significant reductions in emissions in the

communities adjacent to the ports of Los Angeles, Long Beach, and Oakland, where the greatest shipping activity occurs. The proposal will also provide air quality benefits to other coastal regions, particularly near shipping lanes and the other ports.

Outreach Efforts

Since the identification of diesel PM as a toxic air contaminant (TAC) in 1998, the public has been more aware of the health risks posed by the emissions of this TAC. At many of ARB's community outreach meetings over the past few years, the public has raised questions regarding our efforts to reduce exposure to diesel PM. At these meetings, ARB staff told the public about the Diesel Risk Reduction Plan adopted in 2000 and described some of the measures in that plan, including those for marine vessels.

To create a forum for the discussion of marine and port air quality issues, ARB formed the Maritime Air Quality Technical Working Group (Maritime Working Group or "MWG") in late 2001. The MWG provided an opportunity for ARB staff to include the public in the early stages of developing strategies to reduce emissions from marine sources, including the emissions from the existing fleet of ocean-going vessels. From late 2001 to early 2004, ARB held five such meetings. During these meetings, ARB staff discussed a number of regulatory strategies at the concept stage, including the current proposal. Five public workshops or workgroup meetings have also been held since late 2004 to discuss draft language for the proposed regulation. During this process, staff has modified the proposal based on the comments received.

Nearly 400 individuals and/or companies were notified for each workshop through a series of mailings. Notices were posted to ARB's marine and public workshops web sites and e-mailed to subscribers of the marine electronic list server.

Recognizing that other states also have concerns about marine emissions, and that uniformity of requirements should be promoted, ARB set up a States Marine Emission Reduction Group. The ARB staff schedules periodic meetings with this group, which includes regulatory agencies in other states and Canada, including the following: Environment Canada, the Northeast States for Coordinated Air Use Management, the New York State Department of Environmental Conservation, the Puget Sound Clean Air Agency, the Alaska Department of Environmental Conservation, Northeast States Clean Air Foundation, Texas Commission on Environmental Quality, Washington State Department of Ecology, and the Oregon Department of Environmental Equality. During these meetings, status reports are given on the progress of marine air quality projects, including the proposed regulation.

In addition to the public meetings presented in Table I-1, ARB staff and management participated in numerous meetings with industry, government agencies, and environmental groups over the past three years. During these meetings, staff presented information on ARB's plans to regulate emissions from marine vessels, and incorporated the feedback from stakeholders. Some of the groups participating were the Pacific Merchant Shipping Association, International Council of Cruise Lines,

Western States Petroleum Association, Ports of Los Angeles, Long Beach, Oakland, and San Francisco, the U.S. Maritime Administration, U.S. Environmental Protection Agency, U.S. Coast Guard, U.S. Navy, California Maritime Academy, California State Lands Commission, South Coast Air Quality Management District, Santa Barbara County Air Quality Management District, Coalition for Clean Air, Environmental Defense, Natural Resources Defense Council, Union of Concerned Scientists, Citizens for a Better Environment, Wilmington Coalition for a Safe Environment, and San Pedro Homeowners Association.

As a way of inviting public participation and enhancing the information flow between ARB and interested parties, staff created a commercial marine Internet web site (http://www.arb.ca.gov/msprog/offroad/marinevess/marinevess.htm) in 2001. Since that time, staff has consistently made available on the web site all related documents, including meeting presentations and draft versions of the proposed regulatory language. The web site has also provided workshop, meeting notices and materials, and other marine related information, along with serving as a portal to other web sites with related information.

Outreach efforts have also included hundreds of personal contacts via telephone, electronic mail, regular mail, surveys, facility visits, and individual meetings with interested parties. These contacts have included interactions with engine manufacturers and operators, emission control system manufacturers, local, national, and international trade association representatives, environmental, State agencies, military officials and representatives, and other federal agencies.

II. NEED FOR CONTROL OF DIESEL PARTICULATE MATTER

In 1998, the Air Resources Board identified diesel PM as a toxic air contaminant (TAC). Diesel PM is by far the most important TAC and contributes over 70 percent of the estimated risk from air toxic contaminants today. In September 2000, ARB approved the "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles" (Diesel Risk Reduction Plan). The goal of the Diesel Risk Reduction Plan is to reduce diesel PM emissions and the associated cancer risk by 85 percent in 2020. In addition, the Office of Environmental Health Hazard Assessment (OEHHA) identified diesel PM in 2001 as one of the TACs that may cause children or infants to be more susceptible to illness, pursuant to the requirements of Senate Bill 25 (Stats. 1999, ch. 731). Senate Bill 25 also requires ARB to adopt control measures, as appropriate, to reduce the public's exposure to these special TACs (H&SC section 39669.5). In the following sections, we describe the physical and chemical characteristics of diesel PM and discuss the adverse health and environmental impacts from the suite of pollutants emitted by diesel-fueled engines.

A. Physical and Chemical Characteristics of Diesel PM

Diesel engines emit a complex mixture of inorganic and organic compounds that exist in gaseous, liquid, and solid phases. The composition of this mixture will vary depending on engine type, engine age and horsepower, operating conditions, fuel, lubricating oil, and whether or not an emission control system is present. The primary gas or vapor phase components include typical combustion gases and vapors such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), oxides of nitrogen (NOx), reactive organic gases (ROG), water vapor, and excess air (nitrogen and oxygen).

Many of the diesel particles exist in the atmosphere as a carbon core with a coating of organic carbon compounds, or as sulfuric acid and ash, sulfuric acid aerosols, or sulfate particles associated with organic carbon. (Beeson, 1998) The organic fraction of the diesel particle contains compounds such as aldehydes, alkanes and alkenes, and high-molecular weight polycyclic aromatic hydrocarbons (PAH) and PAH-derivatives. Many of these PAHs and PAH-derivatives, especially nitro-PAHs, have been found to be potent mutagens and carcinogens. Nitro-PAH compounds can also be formed during transport through the atmosphere by reactions of adsorbed PAH with nitric acid and by gas-phase radical-initiated reactions in the presence of oxides of nitrogen. Fine particles may also be formed secondarily from gaseous precursors such as SO_2, NOx, or organic compounds. Fine particles can remain in the atmosphere for days to weeks and travel through the atmosphere for hundreds to thousands of kilometers, while coarse particles deposit to the earth within minutes to hours and within tens of kilometers from the emission source.

Almost the entire diesel particle mass is in the fine particle range of 10 microns or less in diameter (PM_{10}). Approximately 94 percent of the mass of these particles are less than 2.5 microns ($PM_{2.5}$) in diameter. Diesel PM can be distinguished from noncombustion sources of $PM_{2.5}$ by the high content of elemental carbon with the

adsorbed organic compounds and the high number of ultrafine particles (organic carbon and sulfate).

The soluble organic fraction (SOF) consists of unburned organic compounds in the small fraction of the fuel and atomized and evaporated lube oil that escape oxidation. These compounds condense into liquid droplets or are adsorbed onto the surfaces of the elemental carbon particles. Several components of the SOF have been identified as individual TACs.

B. Health Impacts of Exposure to Diesel PM, Ambient Particulate Matter, Ozone, and Sulfur Dioxide

The proposed regulation will reduce the public's exposure to diesel PM as well as reduce ambient particulate matter. In addition, the proposed regulation is expected to result in reductions in NOx and SOx. NOx is a precursor to the formation of ozone, and both NOx and SOx also contribute to secondarily formed PM in the lower atmosphere. The primary health impacts of these air pollutants are discussed below.

Diesel Particulate Matter

Diesel PM is of specific concern because it poses a lung cancer hazard for humans as well as a hazard from noncancer respiratory effects such as pulmonary inflammation. (ARB, 1998a) Because of their small size, the particles are readily respirable and can effectively reach the lowest airways of the lung along with the adsorbed compounds, many of which are known or suspected mutagens and carcinogens. (ARB, 2002) More than 30 human epidemiological studies have investigated the potential carcinogenicity of diesel PM. On average, these studies found that long-term occupational exposures to diesel exhaust were associated with a 40 percent increase in the relative risk of lung cancer. (ARB, 1998b) However, there is limited specific information that addresses the variable susceptibilities to the carcinogenicity of diesel exhaust within the general human population and vulnerable subgroups, such as infants and children and people with preexisting health conditions. The carcinogenic potential of diesel exhaust was also demonstrated in numerous genotoxic and mutagenic studies on some of the organic compounds typically detected in diesel exhaust. (ARB, 1998b)

Diesel PM was listed as a TAC by ARB in 1998 after an extensive review and evaluation of the scientific literature by OEHHA. (ARB 1998c) Using the cancer unit risk factor developed by OEHHA for the TAC program, it was estimated that for the year 2000, exposure to statewide average population-weighted ambient concentrations of diesel (1.8 $\mu g/m^3$) could be associated with a health risk of 540 potential cancer cases per million people exposed over a 70 year lifetime.

Another highly significant health effect of diesel exhaust exposure is its apparent ability to act as an adjuvant in allergic responses and possibly asthma. (Dab, 2000; Diaz-Sanchez, 1996; Kittelson, 1999) However, additional research is needed at diesel

exhaust concentrations that more closely approximate current ambient levels before the role of diesel PM exposure in the increasing allergy and asthma rates is established.

Ambient Particulate Matter

The key health effects categories associated with ambient particulate matter, of which diesel PM is an important component, include premature mortality; aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days); aggravated asthma; acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, chronic bronchitis, and decreased lung function that can be experienced as shortness of breath. (U.S. EPA, 2000; U.S. EPA, 2003)

Health impacts from exposure to the fine particulate matter ($PM_{2.5}$) component of diesel exhaust have been calculated for California, using concentration-response equations from several epidemiological studies. Both mortality and morbidity effects could be associated with exposure to either direct diesel $PM_{2.5}$ or indirect diesel $PM_{2.5}$, the latter of which arises from the conversion of diesel NO_x emissions to $PM_{2.5}$ nitrates. It was estimated that 2000 and 900 premature deaths resulted from long-term exposure to either 1.8 $\mu g/m^3$ of direct $PM_{2.5}$ or 0.81 $\mu g/m^3$ of indirect $PM_{2.5}$, respectively, for the year 2000. (Lloyd, 2001) The mortality estimates are likely to exclude cancer cases, but may include some premature deaths due to cancer, because the epidemiological studies did not identify the cause of death. Exposure to fine particulate matter, including diesel $PM_{2.5}$, can also be linked to a number of heart and lung diseases.

Ozone

Diesel exhaust consists of hundreds of gas-phase, particle-phase, and semi-volatile organic compounds, including typical combustion products, such as CO_2, hydrogen, oxygen, and water vapor. Diesel exhaust also includes compounds resulting from incomplete combustion, such as CO, ROG, carbonyls, alkenes, aromatic hydrocarbons, PAHs, PAH derivatives, and SOx. Ozone is formed by the reaction of ROG and NOx in the atmosphere in the presence of heat and sunlight. The highest levels of ozone are produced when both ROG and NOx emissions are present in significant quantities on hot, clear summer days. This pollutant is a powerful oxidant that can damage the respiratory tract, causing inflammation and irritation, which can result in breathing difficulties.

Studies have shown that there are impacts on public health and welfare from ozone at moderate levels. Short-term exposure to high ambient ozone concentrations have been linked to increased hospital admissions and emergency visits for respiratory problems. (Peters, 2001) Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Prolonged (six to eight hours), repeated exposure to ozone can cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature

aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

The population subgroups most susceptible to ozone health effects include individuals exercising outdoors, children and people with preexisting lung disease such as asthma, and chronic pulmonary lung disease. Children are more at risk from ozone exposure because they typically are active outside, during the summer when ozone levels are highest. Also, children are more at risk than adults from ozone exposure because their respiratory systems are still developing. Adults who are outdoors and moderately active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk. These individuals, as well as people with respiratory illnesses such as asthma, especially asthmatic children, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.

Sulfur Dioxide and Sulfates

Sulfur dioxide (SO_2) is a gaseous compound of sulfur and oxygen. SO_2 is formed when sulfur-containing fuel is burned by mobile sources, such as locomotives, vessels, and off-road diesel equipment. SO_2 is also emitted from several industrial processes, such as petroleum refining and metal processing.

SO_2 causes a wide variety of health and environmental impacts because of the way it reacts with other substances in the air. Particularly sensitive groups include people with asthma who are active outdoors and children, the elderly, and people with heart or lung disease. Effects from SO_2 exposures at levels near the one-hour standard include bronchoconstriction accompanied by symptoms, which may include wheezing, shortness of breath and chest tightness, especially during exercise or physical activity. Children, the elderly, and people with asthma, cardiovascular disease or chronic lung disease (such as bronchitis or emphysema) are most susceptible to these symptoms. Continued exposure at elevated levels of SO_2 results in increased incidence of pulmonary symptoms and disease, decreased pulmonary function, and increased risk of mortality.

Sulfates (SO_4^{2-}) are the fully oxidized ionic form of sulfur. Sulfates occur in combination with metal and / or hydrogen ions. In California, emissions of sulfur compounds occur primarily from the combustion of petroleum-derived fuels (e.g., gasoline and diesel fuel) that contain sulfur. This sulfur is oxidized to sulfur dioxide (SO_2) during the combustion process and subsequently converted to sulfate compounds in the atmosphere. The conversion of SO_2 to sulfates takes place comparatively rapidly and completely in urban areas of California due to regional meteorological features. When these are breathed, they gather in the lungs and are associated with increased respiratory symptoms and disease, difficulty in breathing, and premature death. (ARB 1991a,b; ARB 1994a,b; EPA, 2000a)

C. Applicability of the Cancer Potency Factor for Diesel PM to Engines Using Marine Gas Oil, Marine Diesel Oil, or Marine Heavy Fuel Oil

ARB staff, in consultation with OEHHA, has concluded that particulate matter emissions from ocean-going vessel diesel (compression ignition) engines operating on marine gas oil (MGO), marine diesel oil (MDO), or marine heavy fuel oil (HFO) constitute "diesel particulate matter" emissions. As such, the cancer potency factor and chronic reference exposure level for exhaust emissions from diesel-fueled engines, approved by the Scientific Review Panel and adopted by the ARB in 1998, are applicable to exhaust emissions from ocean-going vessel diesel engines using MGO, MDO, or HFO. The basis for staff's conclusion is presented below.

Marine Gas Oil and Marine Diesel Oil

For the following reasons, ARB staff believes the health values developed for diesel PM are appropriate for emissions from diesel engines using MGO and MDO:

- MGO and MDO are distillate fuels with most fuel properties nearly identical to diesel fuel.

Marine gas oil is generally the heavier middle fraction product from the atmospheric distillation of crude oil. Conventional diesel is the lighter middle fraction product from the atmospheric distillation of crude oil. The key fuel properties for marine distillate fuel (MGO and MDO) are very similar to conventional diesel fuel that is used for on-road and off-road diesel engines. The density, heating value, and hydrogen and carbon content for MGO, MDO and conventional diesel fuel are essentially the same. The viscosity of MGO and conventional diesel are very close to the same; while the viscosity of MDO is somewhat higher the MGO or conventional diesel fuel.

The main difference among these fuels is the sulfur content. Since diesel used in on-road and off-road applications are required to meet ARB and U.S. EPA sulfur content limits, conventional diesel fuel generally has lower sulfur content than MGO or MDO. As discussed earlier, the current average sulfur content for MGO used by vessels visiting California ports is about 0.5 percent (5000 ppm). Diesel fuel meeting ARB specification averages about 0.014 percent (140 ppm) and is scheduled to be reduced to 0.0015 percent (15 ppm) in 2006. Generally, MGO will be sold as MDO if it has come in contact with HFO.

- The fuel specifications for MGO and MDO are very similar to the diesel fuel specification that existed prior to 1993.

MGO and MDO fuel specifications are very similar to pre-1993 diesel fuel. Pre-1993 diesel fuels, compared to post-1993 diesel fuel in California, generally had higher aromatic content (33 vs. 20-25 vol. percent), higher sulfur (<5000 vs. 100-150 ppm Wt.), lower cetane number (>40 vs. 50-55), higher PAHs (8 vs. 2-5 Wt. percent) and higher nitrogen (300-600 vs. 40-500 ppm Wt.) (ARB, 1998). This is important in that one of

the key health studies linking increases cancer risk with exposure to diesel exhaust emissions was based on railroad workers exposed to diesel exhaust emissions in the 1950s through 1970s.

Heavy Fuel Oil

The health values developed for diesel PM are also appropriate for emissions from diesel engines using HFO since the basic fuel properties of HFO are similar to diesel fuel, and since emission characteristics from diesel engines using HFO are similar to diesel engines using diesel fuel.

- HFO is a blended petroleum product containing the same classes of hydrocarbons as diesel fuel

Heavy fuel oil, like diesel fuel, is comprised of a complex mixture of aliphatic, naphthenic, and aromatic hydrocarbons. With both types of fuel, the final product will contain varying amounts of these classes of hydrocarbons based on the crude oil used and the refinery process. Heavy fuel oil simply contains a higher proportion of heavier (higher molecular weight - typically having a carbon number from C_{20} to C_{50}) versions of the same hydrocarbon types, and higher levels of sulfur, metals, and other contaminants.

- Heavy fuel oil contains some diesel fuel

Marine fuels may be separated into two basic types of fuels: distillate and residual (EPA, 1999). Distillate fuel (e.g., diesel fuel and marine gas oil) is composed of the fractions of crude oil that are separated in a refinery by a boiling process, while the remaining fraction that did not boil is referred to as residual. To produce fuels that can be conveniently handled and stored in industrial and marine installations, and to meet marketing specifications limits, the high viscosity residual components are normally blended with MGO or similar lower viscosity fractions. (CONCAWE, 1998) For example, the most common grades of marine heavy fuel oil (IFO-380 and IFO-180) are composed of a mixture of residual compounds and distillate components (EPA, 1999; FAMM, 2001). Specifically, typical heavy fuel oil has been estimated to contain as much as 12 percent distillate (EPA, 1999).

- The emission characteristics of a marine diesel engine using HFO are similar to those of a diesel engine using diesel fuel

The diesel engines covered by the proposed regulation are larger versions of typical land-based diesel engines. They operate on a compression-ignition "diesel" cycle similar to land-based diesel engines. Marine diesel engines are designed to burn HFO, MGO, or MDO. The combustion process is nearly identical for any of these fuels. The liquid petroleum based fuel is injected into the engine where it is compressed to the point of auto-ignition. The peak combustion temperatures are similar for all of the fuels. While the relative magnitude of the combustion products may vary with fuel; the relative

percentage of organic material, elemental carbon, and ash are similar among the various fuels. The percent of sulfates and sulfate bound water is higher as the sulfur content of the fuel increases. As a result of the nearly identical combustion process, we would expect that the major combustion products of an engine burning HFO will be similar in chemical nature to an engine using diesel fuel.

- The general classes of PM exhaust components from a marine diesel engine using HFO are similar to a diesel engine using diesel fuel

The PM components emitted from vessel auxiliary engines using heavy fuel oil are the same as those emitted from a typical diesel engine: elemental carbon, ash, soluble organic compounds, and a sulfate fraction (Man B&W, 2004). However, the overall levels of PM will be significantly higher, and a greater proportion of the PM will be from sulfate. Specifically, as discussed in Chapter IV, we estimate that a typical vessel auxiliary engine running on 2.5 percent sulfur heavy fuel oil will emit about 1.5 g of PM per kW-hr. This compares to an emission factor of about 0.3 g/kw-hr for the same engine running on marine gas oil with a sulfur content of about 0.25 percent. Much of this difference is due to the sulfur content of the fuel, since sulfate PM is estimated to be directly related to fuel sulfur. The higher ash content and density of heavy fuel oil is also expected to play a role in the higher emissions from engines using heavy fuel oil (EPA 2002).

- The particle size distribution of the exhaust emissions from a marine diesel engine using HFO is similar to the particle size distribution from a diesel engine using diesel fuel

Preliminary results from testing performed in 2005 by the University of California, Riverside, CE-CERT, in association with Maersk and CARB, indicate that over 85 percent of the particulate matter emissions from a marine diesel engines burning HFO are less than 2.5 microns in size. These results are similar to results for diesel engines using diesel fuel where 95 percent of the particulate were found to be less than 2.5 microns in size. (ARB, 1998) These very small particles are more likely to be inhaled deep into the lung and, as a result, may pose more of a health issue than larger particles.

D. Health and Environmental Benefits from the Proposed Regulation

Reducing diesel PM emissions from vessel auxiliary engines will have both public health and environmental benefits. The proposed regulation will reduce localized health risks associated with the operation of vessel auxiliary engines that are near receptors and will contribute to the reduction of the general exposure to diesel PM that occurs on a region-wide basis due to collective emissions from diesel-fueled engines. Additional benefits associated with the proposed regulation include further progress in meeting the ambient air quality standards for PM_{10}, $PM_{2.5}$, and ozone, and enhancing visibility.

Reduced Diesel PM Emissions

The estimated reductions in diesel PM emissions and the associated benefits from reduced exposure and risk are discussed in detail in Chapter VIII.

Reduced Ambient Particulate Matter Levels

Reducing diesel PM will also help efforts to achieve the ambient air quality standards for particulate matter. Both the State of California and the U.S. EPA have established standards for the amount of PM_{10} and $PM_{2.5}$ in the ambient air. These standards define the maximum amount of PM that can be present in outdoor air. California's PM_{10} standards were first established in 1982 and updated June 20, 2002. It is more protective of human health than the corresponding national standard. Additional California and federal standards were established for $PM_{2.5}$ to further protect public health (Table II-1).

Table II-1: State and National PM Standards

California Standard		National Standard	
PM_{10}			
Annual Arithmetic Mean	20 $\mu g/m^3$	Annual Arithmetic Mean	50 $\mu g/m^3$
24-Hour Average	50 $\mu g/m^3$	24-Hour Average	150 $\mu g/m^3$
$PM_{2.5}$			
Annual Arithmetic Mean	12 $\mu g/m^3$	Annual Arithmetic Mean	15 $\mu g/m^3$
24-Hour Average	No separate State standard	24-Hour Average	65 $\mu g/m^3$

Particulate matter levels in most areas of California exceed one or more of current State PM standards. The majority of California is designated as non-attainment for the State PM_{10} standard (ARB 2002). Diesel PM emission reductions from diesel-fueled engines will help protect public health and assist in furthering progress in meeting the ambient air quality standards for both PM_{10} and $PM_{2.5}$.

The emission reductions obtained from this proposal will result in lower ambient particulate matter levels and significant reductions of exposure to primary diesel and secondary PM resulting from NOx and SOx emissions from auxiliary engines. Lower ambient particulate matter levels and reduced exposure mean reduction of the prevalence of the diseases attributed to diesel PM, reduced incidences of hospitalizations, and prevention of premature deaths.

Reduced Ambient Ozone Levels

Emissions of NOx, a precursor to the formation of ozone in the lower atmosphere, will also be reduced by the proposed regulation. In California, most major urban areas and many rural areas are non-attainment for the State and federal 8-hour ambient air quality

standard for ozone. Controlling emissions of ozone precursors would reduce the prevalence of the types of respiratory problems associated with ozone exposure and would reduce hospital admissions and emergency visits for respiratory problems. Ozone can also have adverse health impacts at concentrations that do not exceed the 8-hour NAAQS. Reducing NOx emissions will also reduce secondarily formed PM (nitrates).

Table II-2: State and National Ozone Standards

	California Standard	National Standard
1 hour	0.09 ppm (180 $\mu g/m^3$)	
8 hour	0.07 ppm (137 $\mu g/m^3$)	0.08 ppm (157 $\mu g/m^3$)

Improved Visibility

In addition to the public health effects of fine particulate pollution, inhalable particulates including sulfates, nitrates, organics, soot, and soil dust contribute to regional haze that impairs visibility.

In 1999, the U.S. EPA promulgated a regional haze regulation that calls for states to establish goals and emission reduction strategies for improving visibility in 156 mandatory Class I national parks and wilderness. California has 29 of these national parks and wilderness areas, including Yosemite, Redwood, and Joshua Tree National Parks. Reducing diesel PM from stationary diesel-fueled engines will help improve visibility in these Class I areas.

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